INSTITUUT VOOR PLANTENZIEKTENKUNDIG ONDERZOEK
WAGENINGEN, NEDERLAND
DIRECTEUR: Dr. J. G. TEN HOUTEN

MEDEDELING No 167, 168 EN 169

CONTROL OF RHIZOCTONIA SOLANI KÜHN IN POTATOES BY DISINFECTION OF SEED TUBERS AND BY CHEMICAL TREATMENT OF THE SOIL

DOOR

J. H. VAN EMDEN

WAARNEMINGEN BETREFFENDE HET PARASITISME VAN PELLICULARIA FILAMENTOSA (PAT.) ROGERS (=RHIZOCTONIA SOLANI KÜHN) TEN OPZICHTE VAN DE AAPDAPPELPLANT

(OBSERVATIONS REGARDING THE PARASITISM OF PELLICULARIA FILAMENTOSA (PAT.) ROGERS (=RHIZOCTONIA SOLANI KÜHN) WITH RESPECT TO THE POTATO PLANT)

DOOR

J. H. VAN EMDEN

RESULTS OF SOME EXPERIMENTS ON THE CONTROL OF COMMON SCAB OF POTATOES BY CHEMICAL TREATMENT OF THE SOIL

DOOR

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OVERDRUK UIT:
EUR. POTATO J., 1(1): 52-64, 1958,
T. PLANTEZ., 64: 276-281, 1958,
EUR. POTATO J., 1(2): 14-24, 1958

NSP
RAM
MM

COMMONWEALTH MYCOLOGICAL INSTITUTE
13 NOV 1958

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CONTROL OF *RHIZOCTONIA SOLANI* KÜHN IN POTATOES BY DISINFECTION OF SEED TUBERS AND BY CHEMICAL TREATMENT OF THE SOIL

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REPRINT FROM EUROPEAN JOURNAL VOL. 1 (1958), No. 1 (MARCH)

CONTROL OF *RHIZOCTONIA SOLANI* KÜHN IN POTATOES BY DISINFECTION OF SEED TUBERS AND BY CHEMICAL TREATMENT OF THE SOIL[1]

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Summary in Eng., G. & Fr., p. 62

INTRODUCTION

The effect of *Rhizoctonia solani* KÜHN on the potato plant is greatly influenced by environmental conditions. In some cases its presence is only apparent through the occurrence of sclerotia on the tubers; in other cases, however, the sprouts may be affected before they emerge from the soil and the plant may be killed altogether. Between these two extremes there are many intermediate degrees of attack. This far reaching influence of environment makes it impossible to predict to what extent the disease will manifest itself in a particular field and thus, to what extent control measures will show effect.

The inoculum of the fungus may be carried on the seed tuber as sclerotia and as mycelium, often to be found in the cavities around the eyes, but may also be present in the soil. Hence, control may be attempted either by seed tuber disinfection or by soil treatment and it is to be expected that control measures aimed at eliminating both sources of infection will be the most effective.

In the present paper we shall discuss the results of experiments in which seed disinfection and soil treatment were applied separately as well as combined. Although the importance of soil, weather conditions and cultural measures is fully appreciated, these are not dealt with in the present paper. Since these experiments were carried out in seed potato growing areas, the effect on the incidence of sclerotia in the crop was used as the main criterion to compare treatments. Yields were also taken, but the small size of the plots does not permit an accurate estimate of the effect on yield of the control measures.

However, the figures obtained suffice to give an indication as to the possible effect on crop size. All experiments were laid out in such a manner as to permit statistical analysis of the results. In order to arrive at an estimate of the amount of black scurf occurring in each plot, a sample of about 5 kg was taken and each tuber classified according to the amount of scurf present. From the weight of the tubers in each class a single figure for the sample was calculated. This method, although laborious, was

[1] Received for publication 12 Dec. 1957.

found to be practicable and the figures obtained lent themselves well to statistical computation. For presentation of the experimental results in this paper we have, however, chosen to state for each treatment the weight of clean tubers expressed as a percentage of total sample weight.

Disinfection of seed potatoes was tried in 1916 by QUANJER (1916), using mercuric chloride at a dilution of 1 : 15,000. The tubers were submerged in the solution for 90 minutes. The experiment was carried out in three localities, in one of which the soil was heavily infested with *Rhizoctonia*. In this latter case the treatment did not result in a cleaner crop, but in the other two the appearance of the harvested tubers was much improved.

In 1918 seed disinfection by soaking the tubers for 90 minutes in a 1 : 10,000 solution of mercuric chloride was tentatively recommended to a number of seed potato-growers by DORST (1920). In some cases an increased yield was obtained, in other cases yield was not found to be influenced and sometimes yield was slightly depressed. The majority of growers, however, reported that the crop obtained from disinfected seed was much cleaner in appearance and more evenly sized.

Abroad, seed disinfection with mercuric chloride was also succesfully tried by CUNNINGHAM (1925), DANA (1925) and STÖRMER (1938).

Although seed disinfection with mercuric chloride and later with organo-mercury compounds became very popular for a time amongst growers of seed potatoes in certain districts in Holland, the practice was later virtually abandoned.

A tentative explanation of this may be that the sclerotia of *R. solani* do not become very conspicuous until towards the end of the growing season and if the crop is lifted early, as was done in later years for the purpose of viruscontrol, it always appears much cleaner than when it has been left in the soil for a longer period. It is also possible, that due to the practice of disinfecting the seed tubers, the level of incidence of the disease was reduced to an extent which led the growers to consider seed disinfection an unnecessary complication of their routine.

Soil treatment with mercury compounds for control of *R. solani* in potatoes was experimented on by MARTIN (1931), VAN DER SLIKKE (1935) and STÖRMER (1938). HOOKER (1935) used pentachloronitrobenzene. Although these authors all obtained favourable results, their methods were not adopted by the growers.

Gradually *R. solani* has again become a serious problem, especially for the growers of seed potatoes who have to comply with stringent regulations of importing countries. Hence it was decided to reinvestigate the effect of seed disinfection as well as the effect of soil treatment for the purpose of *Rhizoctonia* control.

EXPERIMENTAL

Effect of seed treatment and time of lifting. In 1954 a small experiment was planted in which the effect of seed treatment and time of lifting on the incidence of sclerotia was studied. The results are given in Table 1.

TABLE 1. Effect of seed tuber disinfection with an organo-mercury compound and time of lifting on the incidence of sclerotia on the crop

Variety	Treatment of seed	% clean tubers by weight	
		Lifted green	Lifted 24 days after haulm killing
Bintje	Disinfected *(desinfiziert)*	96	92
Eersteling	Disinfected *(desinfiziert)*	95	90
Bintje	Untreated *(Unbehandelt)*	91	79
Eersteling	Untreated *(Unbehandelt)*	91	61
Sorte	*Behandlung der Saatknollen*	*Grün gerodet*	*24 Tage nach der Krauttötung gerodet*
		Gewichtsprozente reiner Knollen	

TABELLE 1. *Wirkung der Saatkartoffeldesinfektion mittels organischer Quecksilberverbindung und Einfluss des Rodungszeitpunkts auf den Sklerotienbefall der Ernte*

These figures show, that if the crop was lifted green, there was little difference in the incidence of sclerotia. If the crop was left in the soil for 24 days after haulm killing, the difference was much greater.

The effect of disinfection of the soil, absence or presence of sclerotia in the tubers and seed disinfection. In 1955 two factorial experiments were carried out. The treatments were (a) disinfection of the soil, (b) absence or presence of sclerotia on the tubers and (c) seed disinfection.

In one experiment two soil treatments were tried; pentachloronitrobenzene at 200 kg/ha and zineb at 13 kg/ha. Seed disinfection was done in November with an organo-mercury compound. The results of these experiments are given in Table 2, p. 55.

In these experiments the treatments 010, 110 and 210 show a considerably lower percentage of clean tubers than the treatments 011, 111 and 211. This indicates that disinfection of seed tubers bearing sclerotia was very effective in reducing the incidence of sclerotia on the crop. Disinfection of apparently clean seed tubers also resulted in a cleaner crop as may be seen from a comparison of the treatments 000, 100 and 200 on one hand and treatments 001, 101 and 201 on the other. Comparison of treatments 001, 101 and 201 with treatments 011, 111 and 211 shows that clean seed tubers when disinfected give a cleaner crop than do sclerotia bearing tubers when disinfected. This indicates that the seed treatment carried out was not powerful enough to kill the inoculum on the sclerotia bearing tubers quantitatively. In neither experiment did the soil treatment result in a cleaner crop, probably because the application was made intentionally as late as feasible, viz. six weeks after planting, when the field was harrowed for the last time.

In both experiments treatments 010, 110 and 210 gave the lowest yield, these treat-

TABLE 2. Effect of soil treatment, occurrence of sclerotia on the seed tuber and seed disinfection on the incidence of sclerotia on the crop

Code	Experiment 1955 (1)		Experiment 1955 (2)	
abc	% clean tubers by weight	Yield in g/plant	% clean tubers by weight	Yield in g/plant
000	42	677	51	525
001	72	671	75	489
010	15	547	3	430
011	62	622	35	542
100	53	666		
101	60	703		
110	21	560		
111	75	667		
200	57	627	54	497
201	73	617	69	481
210	17	509	2	428
211	57	617	39	506
abc	*Gewichtsprozente reiner Knollen*	*Ertrag in Gramm je Pflanze*	*Gewichtsprozente reiner Knollen*	*Ertrag in Gramm je Pflanze*
Code	*Versuch 1955 (1)*		*Versuch 1955 (2)*	

TABELLE 2. *Ergebnis der Bodenbehandlung, Vorkommen von Sklerotien auf den Saatkartoffeln und Wirkung der Saatkartoffeldesinfektion auf den Sklerotienbefall der Ernte*

Significance of data on occurrence of *Rhizoctonia* in the crop

Sicherheit der Daten betreffs das Vorkommen von Rhizoctonia in der Ernte

Experiment 1955 (1) *Versuch 1955 (1)*

F (a) = 1 F (0.05) = 3.5
F (b) = 7.94 F (0.05) = 4.4
F (c) = 25.29 F (0.01) = 8.2

Experiment 1955 (2) *Versuch 1955 (2)*

F (a) = 1 F (0.05) = 4.6
F (b) = 78 F (0.01) = 8.9
F (c) = 26 F (0.01) = 8.9

Explanation of code

(a) 0 soil not treated
 1 soil treated with zineb 13 kg/ha
 2 soil treated with PCNB 200 kg/ha
(b) 0 seed tubers free from sclerotia
 1 seed tubers with sclerotia
(c) 0 seed not treated
 1 seed disinfected with organo-mercury compound[1]

Erklärung des Code

(a) 0 *nichtbehandelter Boden*
 1 *Boden, behandelt mit Zineb 13 kg/ha*
 2 *Boden, behandelt mit PCNB 200 kg/ha*
(b) 0 *Saatkartoffeln sklerotienfrei*
 1 *Saatkartoffeln mit Sklerotien behaftet*
(c) 0 *Saatkartoffeln nicht behandelt*
 1 *Saatkartoffeln desinfiziert mittels organischer Quecksilberverbindung*[1]

[1] The organo-mercury compound used in these experiments is a proprietary product, the active ingredient of which is known to the author.

[1] *Die bei diesen Versuchen zur Verwendung gelangte organische Quecksilberverbindung ist ein patentamtlich geschütztes Produkt, dessen aktiv wirkender Bestandteil dem Autor bekannt ist.*

ments being those for which sclerotia bearing tubers were used without previous disinfection. When the crop from the experimental plots was graded according to size, it was found that these same treatments had produced more tubers larger than 45 mm than any of the other treatments. Since tubers of over 45 mm are not acceptable as seed, this is an additional reason for seed disinfection. This effect on size may be explained by the fact that the plants in the plots grown from disinfected seed had developed more stems than the plants grown from untreated seed, as is shown in Table 3.

TABLE 3. Influence of seed disinfection on tuber size and on the number of stems per plant

Treatment	Percentage of the crop in the size brackets				Average number of stems/plant	Behandlung
	< 28 mm	28–35 mm	35–45 mm	> 45 mm		
clean seed untreated	8.8	41.9	42.5	3.7	11.8	*reines Saatgut unbehandelt*
clean seed disinfected	9.3	44.7	44.6	1.4	13.6	*reines Saatgut desinfiziert*
seed with sclerotia untreated	8.2	30.3	46.8	14.7	8.2	*Saatgut mit Sklerotien unbehandelt*
seed with sclerotia disinfected	10.4	44.1	44.0	2.1	10.5	*Saatgut mit Sklerotien desinfiziert*
	Prozentsatz der Ernte nach Grössenklasse				*Mittelzahl der Stengel je Pflanze*	
	< 28 mm	*28–35 mm*	*35–45 mm*	*> 45 mm*		
	F = 13.7 F (0.01) = 8.2				F = 8.05 F (0.05) = 4.4	

TABELLE 3. *Einfluss der Saatkartoffeldesinfektion auf die Grösse der Kartoffelknollen und auf die Zahl der Krautstengel je Pflanze*

Apart from these two factorial experiments, a block experiment was planted in which soil treatment was applied at the time of planting. The results are given in Table 4.

TABLE 4. Influence of soil disinfection on the occurrence of sclerotia in the crop

Treatment	% of clean tubers by weight	Yield in grams/plant
Zineb 13 kg/ha	12	716
Zineb 27 kg/ha	22	716
PCNB 200 kg/ha	76	658
Untreated	18	674
Behandlung	*Gewichtsprozente reiner Knollen*	*Ertrag in Gramm je Pflanze*
	F = 37.6 F (0.01) = 9.8	

TABELLE 4. *Einfluss der Bodenbehandlung auf das Vorkommen von Sklerotien in der Ernte*

These figures show that zineb had no effect on the appearance of the crop. The increased yield is probably due to a nutritional effect. PCNB greatly increased the percentage of clean tubers in the crop but appears to have caused a slight reduction of yield.

The effect of soil treatment with PCNB at a low rate (100 kg/ha)

In 1956 another experiment was carried out. Zineb was not used any more, but instead PCNB was tried at a lower rate. The incidence of *Rhizoctonia* was generally at a lower level in 1956 than it had been in 1955 as may be seen from the results of the 1956 experiment given in Table 5.

TABLE 5. Influence of seed disinfection and soil treatment on appearance of crop and on yield

Treatment code abc	% clean tubers by weight	Yield in g/plant
000	87	700
001	88	725
010	57	700
011	86	665
100	94	620
101	93	660
110	88	615
111	94	545
200	94	685
201	99	560
210	97	570
211	95	625
abc Code Behandlung	*Gewichtsprozente reiner Knollen*	*Ertrag in Gramm je Pflanze*

TABELLE 5. *Einfluss der Saatkartoffeldesinfektion und der Bodenbehandlung auf das Auflaufen der Kartoffelpflanzen und auf den Ernteertrag*

Statistical significance of data on occurrence of *Rhizoctonia*
F (a) = 4.43
F (b) = 2.60
F (c) = 2.89

Sicherheit der Daten betreffs das Vorkommen von Rhizoctonia
F (0.05) = 3.5
F (0.05) = 4.4
F (0.05) = 4.4

Explanation of code:
(a) 0 soil not treated
1 soil treated with PCNB 100 kg/ha
2 soil treated with PCNB 200 kg/ha
(b) 0 seed tubers free from sclerotia
1 seed tubers with sclerotia
(c) 0 seed not treated
1 seed disinfected with organo-mercury compound

Erklärung des Code:
(a) 0 *nichtbehandelter Boden*
1 *Boden, behandelt mit PCNB 100 kg/ha*
2 *Boden, behandelt mit PCNB 200 kg/ha*
(b) 0 *Saatkartoffeln sklerotienfrei*
1 *Saatkartoffeln mit Sklerotien behaftet*
(c) 0 *Saatkartoffeln nicht behandelt*
1 *Saatkartoffeln desinfiziert mittels organischer Quecksilberverbindung*

TABLE 6. Influence of seed disinfection and soil treatment with PCNB at different times of application on appearance of crop and on yield

Treatment code abc	% clean tubers by weight	Yield in g/plant
000	38	586
001	75	631
002	55	556
010	11	607
011	56	601
012	36	554
100	35	622
101	72	601
102	55	633
110	10	528
111	58	633
112	29	532
200	60	647
201	76	612
202	73	573
210	38	594
211	80	617
212	57	615
abc Code Behandlung	*Gewichtsprozente reiner Knollen*	*Ertrag in Gramm je Pflanze*

TABELLE 6. *Einfluss der Saatkartoffeldesinfektion und der Bodenbehandlung mit PCNB zu verschiedenen Anwendungszeiten auf das Auflaufen der Kartoffelpflanzen und auf den Ernteertrag*

Statistical significance of data on occurrence of *Rhizoctonia* in crop

F (a) = 24.40
F (b) = 16.01
F (c) = 31.95

Sicherheit der Daten betreffs das Vorkommen von Rhizoctonia in der Ernte

F (0.01) = 10.9
F (0.01) = 7.2
F (0.01) = 5.1

Explanation of code:

(a) 0 soil not treated
  1 soil treated with PCNB 100 kg/ha in January
  2 soil treated with PCNB 100 kg/ha in April
(b) 0 seed tubers free from sclerotia
  1 seed tubers with sclerotia
(c) 0 no seed disinfection
  1 seed disinfected with organo mercury compound
  2 seed disinfected with formaldehyde vapour

Erklärung des Code:

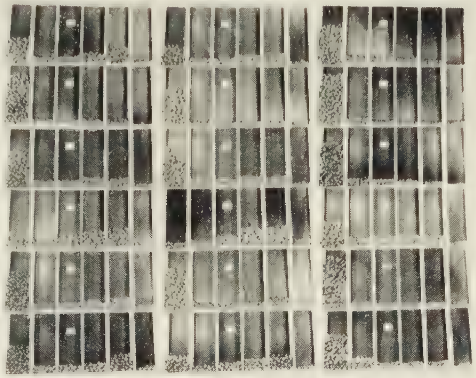
(a) 0 *nichtbehandelter Boden*
  1 *Boden, behandelt mit PCNB 100 kg/ha im Januar*
  2 *Boden, behandelt mit PCNB 100 kg/ha im April*
(b) 0 *Saatkartoffeln sklerotienfrei*
  1 *Saatkartoffeln mit Sklerotien behaftet*
(c) 0 *keine Saatkartoffeldesinfektion*
  1 *Saatkartoffeln desinfiziert mittels organischer Quecksilberverbindung*
  2 *Saatkartoffeln desinfiziert durch Formaldehyd-Dämpfen*

Fig. 1. The harvest of the 1957 *Rhizoctonia* control experiment (see table 6) graded according to the amount of black scurf occurring on the tubers

Soil not treated | Soil treated with PCNB at 100 kg/ha in January | Soil treated with PCNB at 100 kg/ha in April

Seedtubers clean:
- Seed tubers not disinfected
- Seed disinfected with organo-mercury compound
- Seed disinfected with formaldehyd vapour

Seedtubers with sclerotia:
- Seed tubers not disinfected
- Seed disinfected with organo-mercury compound
- Seed disinfected with formaldehyd vapour



Sklerotienfrei:
- *Saatkartoffeln nicht desinfiziert*
- *Saatkartoffeln desinfiziert mit organischer Quecksilberverbindung*
- *Saatkartoffeln desinfiziert mit Formaldehyd-Dämpfen*

Mit Sklerotien:
- *Saatkartoffeln nicht desinfiziert*
- *Saatkartoffeln desinfiziert mit organischer Quecksilberverbindung*
- *Saatkartoffeln desinfiziert mit Formaldehyd-Dämpfen*

Boden unbehandelt | Boden behandelt mit PCNB 100 kg/ha im Januar | Boden behandelt mit PCNB 100 kg/ha im April

At left the clean tubers and at right the severely affected tubers
Links die reinen und rechts die stark befallenen Saatkartoffeln

Fig. 1. *Die Ernte des Rhizoctonia-bekämpfungsversuchs 1957 (siehe Tabelle 6) gruppiert nach der Stärke des Schorfbefalls auf den Knollen*

This experiment shows the lowest percentage of clean tubers for treatment 010 in which no soil treatment or seed disinfection was applied and for which tubers bearing sclerotia were used. Both soil treatments appear effective in improving the appearance of the crop but there was a significant depression of yield caused by the soil treatment with PCNB at both levels of application.

The effect of early application (January) of PCNB. Since PCNB had given good control of *Rhizoctonia* in two successive years it was decided to try whether the undesirable effect of delaying emergence might be eliminated by applying the chemical at an earlier date instead of doing so at the time of planting.
The following year (1957), therefore, a very early application (January) was made before ploughing. For comparison another treatment was included in which application was made at the time of planting by broadcasting the chemical over the plots immediately after setting the tubers. The results of the experiment are given in Table 6 and in Fig. 1.
These figures show that again the lowest percentage of clean tubers came from the treatments in which seed tubers bearing sclerotia were used without seed disinfection. Seed disinfection with organo-mercury compound was more effective than the treatment with formaldehyde-vapour. The early soil treatment, applied in January, was clearly ineffective. Probably the fungicide got too deeply buried by ploughing. The application of PCNB at 100 kg/ha immediately after planting significantly improved the appearance of the crop. Yield figures are erratic and no conclusions can be drawn from them. This is probably due to the fact that the field suffered from drought.

Some other observations
Apart from these experiments designed for the purpose of investigating the control of *R. Solani*, observations on the incidence of the disease were made in two more experiments designed primarily for investigating the control of common scab bij chemical treatment of the soil. The treatments used were PCNB at 60 kg/ha and at 90 kg/ha, mercuric chloride at 16 kg/ha and sulphur at 200 kg/ha. The results are given in Tables 7 and 8.

The figures in Table 7 show an overall decrease in the percentage of clean tubers between the two dates of lifting. This confirms the results obtained in 1954 with regard to the influence of time of lifting on the incidence of sclerotia (see Table 1).
Both Tables 7 and 8 show that PCNB and mercuric chloride were effective in reducing the incidence of sclerotia in the crop.

TABLE 7. Influence of soil treatment with PCNB, mercuric chloride and sulphur on the incidence of *R. solani*
Variety „Eigenheimer", seed not disinfected

Treatment	% clean tubers by weight		Yield in grams/plant	
	A[1]	B[1]	A[1]	B[1]
PCNB 60 kg/ha	69	47	632	877
PCNB 90 kg/ha	75	56	632	823
$HgCl_2$ 16 kg/ha	60	29	692	856
Sulphur 200 kg/ha . . .	20	1	695	876
Control untreated . . .	10	0	657	831
Behandlung	*Gewichtsprozente reiner Knollen*		*Ertrag in Gramm je Pflanze*	

TABELLE 7. *Einfluss der Bodenbehandlung mit PCNB, Quecksilberchlorid und Schwefel auf das Vorkommen von Rhizoctonia solani*
Sorte „Eigenheimer", Saatkartoffeln nicht desinfiziert

Significance of data on occurrence of *Rhizoctonia*
F (soil treatment) = 30.4 for crop lifted 29/7
F (soil treatment) = 26.4 for crop lifted 9/9
F (0.01) = 9.8

Sicherheit der Daten betreffs das Vorkommen von Rhizoctonia
F *(Bodenbehandlung) = 30.4 für Ernte gerodet am 29/7*
F *(Bodenbehandlung) = 26.4 für Ernte gerodet am 9/9*
F (0.01) = 9.8

[1] A = Lifted 29/7 after haulm killing 19/7.
B = Lifted 9/9 after haulm killing 29/7.

A = *Gerodet 29/7 nach Krauttötung 19/7.*
B = *Gerodet 9/9 nach Krauttötung 29/7.*

TABLE 8. Influence of soil treatment with PCNB, mercuric chloride and sulphur on the incidence of *R. solani*
Variety „Noordeling", seed not disinfected

Treatment	% clean tubers by weight	Yield in grams/plant
PCNB 60 kg/ha	87	579
PCNB 90 kg/ha	93	546
$HgCl_2$ 16 kg/ha	96	553
Sulphur 200 kg/ha	71	596
Control untreated	50	573
Behandlung	*Gewichtsprozente reiner Knollen*	*Ertrag in Gramm je Pflanze*

TABELLE 8. *Einfluss der Bodenbehandlung mit PCNB, Quecksilberchlorid und Schwefel auf das Vorkommen von R. solani*
Sorte „Noordeling", Saatkartoffeln nicht desinfiziert

Significance of data on incidence of *Rhizoctonia*
F (soil treatment) = 10.98
F (0.01) = 9.8

Sicherheit der Daten betreffs das Vorkommen von Rhizoctonia
F *(Bodenbehandlung) = 10.98*
F *(0.01) = 9.8*

DISCUSSION AND CONCLUSIONS

In four years of experiments on the control of *R. solani* it was found that disinfection of seed tubers may considerably reduce the incidence of sclerotia on the crop. This effect may be produced, even if the seed tubers appear to be free from sclerotia as mycelial threads of the fungus may be present in the cavities around the eyes.

In all experiments it was found that even if disinfection is practised, clean seed tubers produce a cleaner crop than sclerotia-bearing tubers. This indicates that the methods of disinfection used did not kill the fungus inoculum quantitatively. Testing of sclerotia removed from disinfected seed tubers, by incubation on water-agar for four days at 20°C, showed that about 20 per cent were still capable of germinating. Mycelial growth from sclerotia removed from treated tubers was, however, slow as compared to that from untreated sclerotia. Apparently, however, even an incomplete disinfection of seed tubers may suffice to improve significantly the appearance of the resulting crop.

On the other hand the incompleteness of the methods of disinfection used, may explain why in some parts of the country potatogrowers do not seem to derive any benefit from seed disinfection. Further experiments in such districts appear to be necessary.

Disinfection of soil by application of pentachloronitrobenzene (PCNB) at the rate of 60–90 kg active substance/ha considerably improves the appearance of the crop. Such treatment may be economical for growers of high quality potato seed if *Rhizoctonia* is a problem.

Broadcasting the chemical at the time of planting appears to be an effective method of application. In one experiment the effect of PCNB was completely suppressed by ploughing the land after broadcasting the powder. Application of PCNB or mercuric chloride retards emergence, which may result in loss of crop especially if the growing period is artificially shortened by haulm killing.

Depression of yield is most noticeable in the years when *Rhizoctonia* is not severe. If the disease is prevalent the retarding effect of PCNB and mercuric chloride is to a large extent compensated by the *Rhizoctonia* control obtained.

In those cases where observations were made as to the effect of time of harvest on the amount of black scurf on the tubers, it was found that *the number of sclerotia increased considerably with the time the tubers were left in the soil.*

Acknowledgement. Thanks are due to Dr. A. R. WILSON for correction of English text and helpful suggestions.

SUMMARY

CONTROL OF *RHIZOCTONIA SOLANI* KÜHN IN POTATOES BY DISINFECTION OF SEED TUBERS AND BY CHEMICAL TREATMENT OF THE SOIL

1 Disinfection of seed tubers with proprietary organo-mercury compounds effectively controls *Rhizoctonia solani* in the seed potato growing area of Noord-Holland.

2 The beneficial effect of disinfection is also produced if the seedtubers do not bear sclerotia, because the fungus inoculum may be present as mycelial threads in the cavities around the eyes.

3 The methods of disinfection used did not

damage the germinative powers of the seed tubers.

4 Soil treatment with Pentachloronitrobenzene at 60–90 kg active substance per ha or with mercuric chloride at 16 kg/ha also controls *Rhizoctonia solani*. Broadcasting the chemicals at the time of planting is an effective method of application. If *Rhizoctonia* is not prevalent the treated plots show a delayed emergence as compared with the untreated; this may result in loss of crop.

5 The amount of black scurf occurring on the tubers increases with the time they are left in the soil.

ZUSAMMENFASSUNG

BEKÄMPFUNG VON *RHIZOCTONIA SOLANI* KÜHN IN KARTOFFELN DURCH DESINFIZIERUNG VON SAATKNOLLEN UND DURCH CHEMISCHE BEHANDLUNG DES BODENS

1 Desinfizierung von Saatknollen mit patentierten organischen Quecksilberverbindungen ist ein wirkungsvolles Bekämpfungsmittel für *Rhizoctonia solani* im Saatkartoffel-anbaugebiet Nordhollands.

2 Die günstige Wirkung der Desinfektion wird auch hervorgerufen, wenn die Saatknollen keine Skletorien tragen, denn die Pilzkeime können anwesend sein als Myzelfäden, in den Vertiefungen um die Augen herum.

3 Die angewandten Desinfektionsverfahren schädigten die Keimkraft der Saatknollen nicht.

4 Bodenbehandlung mit Pentachloronitrobenzen (60 bis 90 kg aktiver Stoff je Hektar) oder mit Quecksilberchlorid (16 kg je Hektar) kann ebenfalls zur Bekämpfung von *Rhizoctonia solani* dienen. Das Ausstreuen der Chemikalien in der Pflanzzeit ist eine effektvolle Anwendungsmethode. Wenn *Rhizoctonia* nicht vorherschend ist, dann zeigen die behandelten Parzellen ein verspätetes Auflaufen im Vergleich zu den unbehandelten Parzellen; dies kann zu Ernteverlusten führen.

5 Die Menge schwarzen Schorfs, die auf den Knollen vorkommt, nimmt zu in der Zeit, in der die Knollen in der Erde gelassen werden.

RÉSUMÉ

LA LUTTE CONTRE *RHIZOCTONIA SOLANI* KÜHN DANS DES CULTURES DE POMMES DE TERRE INFESTÉES PAR DÉSINFECTION DES PLANTS ET TRAITEMENT CHIMIQUE DU SOL

1 La désinfection de plants de pommes de terre par des combinaisons organiques de mercure se montre un moyen efficace dans la lutte contre le rhizoctone des tubercules de pommes de terre dans la province de Hollande septentrionale.

2 La désinfection a donné de bons résultats même dans les cas où les tubercules ne sont pas atteints par sclérotia, du fait que le champignon peut être présent dans les cavités autour des yeux sous forme de mycélium.

3 Les méthodes de désinfection pratiquées n'ont pas nui aux forces germinatives des plants.

4 Un traitement du sol à pentachloronitrobenzène contenant 60 à 90 kg de substance active à l'hectare, ou bien à chlorure mercurique à 16 kg par hectare, combat également la gale rhizoctonienne. Très efficace s'avère, au surplus, l'utilisation de produits chimiques au moment de la plantation. Lorsque les cultures ne sont pas infestées par la gale rhizoctonienne, les terres traitées démontrent une croissance tardive de la végétation en présence de témoins. Une perte partielle de la moisson peut en résulter.

5 Plus la période pendant laquelle la pomme de terre demeure dans le sol, est longue, plus la chance d'infestation des tubercules par la gale rhizoctonienne est grande.

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WAARNEMINGEN BETREFFENDE HET PARASITISME VAN *PELLICULARIA FILAMENTOSA* (PAT.) ROGERS (= *RHIZOCTONIA SOLANI* KÜHN) TEN OPZICHTE VAN DE AARDAPPELPLANT

T. Pl.ziekten 64 (1958): 276–281

WAARNEMINGEN BETREFFENDE HET PARASITISME VAN *PELLICULARIA FILAMENTOSA* (PAT.) ROGERS (= *RHIZOCTONIA SOLANI* KÜHN) TEN OPZICHTE VAN DE AARDAPPELPLANT[1])

With a summary:
Observations regarding the parasitism of Pellicularia filamentosa (*Pat.*) *Rogers* (Rhizoctonia solani *Kühn*) *with respect to the potato plant*

DOOR

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INLEIDING

Indien in een aardappelaanplant de Rhizoctonia-ziekte optreedt, blijkt dit vaak door een onregelmatige stand van het gewas, die wordt veroorzaakt doordat de aangetaste planten in groei achterblijven of een afwijkende habitus hebben. Indien men in een dergelijk onregelmatig perceel een proefperk uitzet en de daarin voorkomende planten op de aanwezigheid van de schimmel en tevens op aantasting onderzoekt, ziet men, dat de schimmel niet alleen voorkomt op de in groei achterblijvende planten, maar soms ook rijkelijk op wortels, stengels en stolonen van planten, die geen enkel teken van aantasting vertonen. De achterlijke planten en de planten die bovengronds ziekteverschijnselen te zien geven, hebben daarentegen steeds necrotische plekken op de ondergrondse delen der stengels of op de stolonen. Hoewel door schrijver dezes vele planten werden onderzocht, werden nooit planten met aangetaste wortels gevonden. Dit geeft de indruk, dat in het algemeen de wortel van de aardappelplant veel minder aan aantasting door de schimmel onderhevig is dan de stengel. Dit wordt ook vermeld door Richter & Schneider (1951), aan wie het volgende citaat is ontleend: „Durch diesen Befund findet unsere bei Infektionsversuche immer wieder gemachte Feststellung, dasz die Wurzel im Gegensatz zum Sprosz schwächer, häufig gar nicht von *R. solani* befallen wird, eine gute Bestätigung... Danach würde also der „Wurzeltöter der Kartoffel" seinen Namen sogar zu unrecht tragen."

Braun (1925) geeft in zijn monografie „Der Wurzeltöter der Kartoffel" in het hoofdstuk „Krankheitssymptome der Kartoffel" een overzicht van de verschillende manieren, waarop *R. solani* zich op de aardappelplant voordoet. Een beschrijving van een aantasting van de wortels is daar echter niet bij; hieruit mag men wel afleiden, dat wortelaantasting door *Rhizoctonia* geen algemeen verschijnsel bij de aardappel is.

Müller (1924) heeft echter wel wortelaantasting waargenomen; hij geeft een beschrijving van de wijze waarop deze tot stand komt. Dana (1925) zegt: „...Root injury occurs to roots of all sizes; injury to feeding roots is one of the most serious effects of the disease".

Een verklaring voor deze uiteenlopende uitspraken kan gelegen zijn in het

[1]) Aangenomen voor publikatie 21 mei 1958.

voorkomen van fysiologische rassen met verschillende eigenschappen. FLENTJE & SASKENA (1957) onderzochten 68 isolaties van *Pellicularia filamentosa* en vonden dat 54 daarvan alleen stengeldelen aantastten; deze isolaties waren specifiek pathogeen op één of enkele families. Dertien isolaties tastten speciaal wortels aan en waren niet specifiek in hun pathogeniteit. Eén isolatie was niet pathogeen.

Behalve door het veroorzaken van necrosen zou de schimmel het wortelstelsel ook kunnen beschadigen door het afscheiden van toxische stoffen, zoals KERR (1956) mededeelt. Het feit, dat men op de wortels van de aardappelplant geen door *P. filamentosa* veroorzaakte verwonding aantreft, is dus nog geen bewijs dat de schimmel geen schade doet aan de ontwikkeling van de plant. Om hieromtrent gegevens te verkrijgen werd een potproef genomen waarin planten, die met hun wortels in besmette aarde groeiden, werden vergeleken met planten, waarvan de wortels zich in niet besmette aarde bevonden. Hierbij werd gezorgd, dat in geen van beide gevallen de schimmel met de stengelgedeelten in contact kon komen.

Teneinde het verschil in vatbaarheid tussen stengel en wortel voor aantasting door *P. filamentosa* nader te bewijzen, werden ook aardappelplantjes tezamen met de schimmel gekweekt op Knop-agar, onder uitsluiting van andere microorganismen.

METHODEN

A. *De invloed van de aanwezigheid van de schimmel op de wortels van de aardappelplant op de groei*

Twee Mitscherlich-potten werden door een slang van 60 cm lengte met elkaar verbonden. De ene pot werd 15 cm hoger geplaatst dan de andere en tot de helft gevuld met gestoomde grond. In de andere pot werd water gedaan tot het niveau de hoogte van de bodem van de eerste pot bereikte. Deze opstelling diende om later de plant van onder af met water te kunnen voorzien (fig. 1). In de gestoomde grond werd een spruit gepoot van een plant die zich in gestoomde grond had ontwikkeld. Deze spruit, met een lengte van ongeveer 15 cm, werd van de moederknol afgebroken. De wortels werden rechtstandig in een

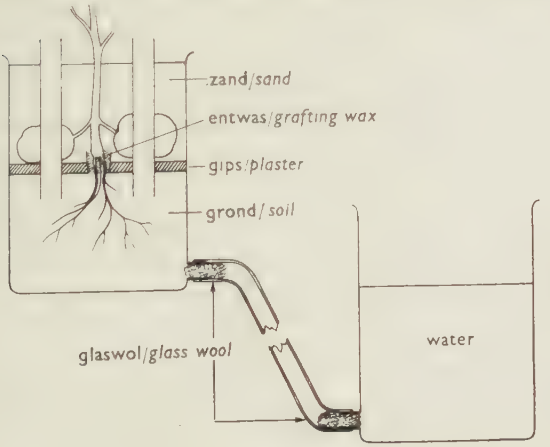

FIG. 1. Methode om aardappelplant op te kweken met de wortels in geïnfecteerde grond, zonder dat stengel en stolonen aan infectie worden blootgesteld.
Method for growing a potato plant with the roots in inoculated soil, preventing contact of stem and stolons with the inoculum.

vooraf gemaakt pootgat gebracht, waarna de grond zorgvuldig werd aangedrukt. Hierbij bleef de stengel ongeveer 1½ cm boven de grond. Het plantje stond dus als het ware op steltwortels. Om de basis van de stengel en het boven de grond uitstekende gedeelte van de wortels werd een cylindertje van aluminiumfolie aangebracht. Dit cylindertje werd gevuld met vloeibare entwas. In de aarde werden nu twee glazen buizen geplaatst; deze waren aan beide kanten open en hadden een doorsnede van 2 cm. De bovenkant van deze buizen stak boven de rand van de pot uit. Op de aarde werd nu een laag gips van ongeveer 1 cm dikte gegoten. Na het verharden van het gips werd de pot verder met droog zand gevuld. In het geheel werden 6 potten op deze wijze behandeld; bij drie daarvan werd de grond geïnfecteerd door vlak bij de wortels een aantal sclerotiën van *P. filamentosa*, verkregen van een besmette partij aardappelen, aan te brengen. De proef werd later herhaald met 22 potten, waarvan 11 geïnfecteerd werden.

B. *Vergelijking van de vatbaarheid van stengel- en wortelgedeelten voor aantasting door* P. filamentosa *in vitro*

In Erlenmeyerkolven van 500 ml inhoud werd een laagje Knop-agar ter dikte van ongeveer 1 cm gegoten. De kolven werden voorzien van een wattenprop en in de autoclaaf gesteriliseerd. Na afkoeling werd midden in de agar een gat gemaakt; hierin werden ongeveer 4 cm lange spruiten van het ras Bintje gepoot, die van te voren gedurende 2 minuten gedesinfecteerd waren in calciumhypochloriet (4 g calciumhypochloriet schudden met 100 ml water en affiltreren). De spruiten verdroegen de desinfectie goed en ontwikkelden zich snel op de agar. Toen de wortels een lengte van enige cm bereikt hadden, werd op een wortel een stukje van een reincultuur van *R. solani* aangebracht. Behalve Knop-agar werd ook wel Knop-agar plus 5 % saccharose als voedingsbodem gebruikt; de schimmel ontwikkelde zich op dit substraat veel sterker.

RESULTATEN

A. *Groei van aardappelplanten met* P. filamentosa *op de wortels, vergeleken met de groei van planten zonder* P. filamentosa

De op de boven beschreven wijze behandelde planten groeiden normaal. In het droge zand boven de gipsplaat ontwikkelden zich geen wortels en onder de gipsplaat in de aarde ontstonden geen stolonen. In het zand werden enige knollen gevormd. Toen de planten tekenen van afrijping vertoonden, werden zij gerooid en het gewicht van de gehele plant werd bepaald. De planten, waarvan de wortels in niet geïnfecteerde grond groeiden, bereikten gemiddeld een totaal gewicht van 360 g per plant terwijl de planten waarvan de wortels groeiden in met *P. filamentosa* besmette grond een gemiddeld gewicht bereikten van 355 g. Dit verschil was kleiner dan de middelbare fout en dus te verwaarlozen. Bij onderzoek van het wortelstelsel der laatstgenoemde planten kon de schimmel daar duidelijk op worden waargenomen in de vorm van het bekende bruine mycelium.

B. *Vergelijking van de vatbaarheid van stengel en wortel van de aardappelplant voor aantasting door* P. filamentosa *in vitro*

De eerste serie kolven werd in de laboratoriumruimte voor het raam gezet.

Ongeveer een week na het aanbrengen van het inoculum van *P. filamentosa* ontstonden op de stengel scherp omgrensde bruine vlekken. Na twee weken waren de stengels geheel afgestorven, terwijl de wortels nog geheel blank waren (fig. 2). In de dode stengels kon *P. filamentosa* worden aangetoond. Bij onderzoek van de wortels onder een prepareermicroscoop bleek, dat het mycelium van de schimmel in ruime mate buiten op de wortels was te vinden. Het was langs de wortel naar de stengel toegegroeid.

De proef werd herhaald met een groter aantal kolven. Deze werden echter niet in de laboratoriumruimte gehouden, doch kregen een plaats in het warenhuis, waar in verband met de inmiddels korter geworden dagen gedurende enige uren per dag extra licht werd gegeven door middel van TL-buizen. Na twee weken was in deze serie nog geen aantasting opgetreden. Wel werden schimmeldraden waargenomen tegen de wand van de kolven. Een aantal planten werd voor onderzoek in het laboratorium gebracht; binnen enige dagen trad daarbij een zeer duidelijke aantasting op. De planten in het warenhuis bleven echter gezond; pas na vier weken werden daar de eerste symptomen van aantasting gezien en wel in de vorm van een bruine verkleuring der jongste blaadjes. Bij onderzoek bleek, dat de schimmel over de wortel en de stengel was gegroeid zonder aantasting te veroorzaken. In de blaadjes groeide de schimmel intercellulair. Later ontstonden ook vlekken op de oudere bladeren en tenslotte werd ook de stengel via de bladstelen aangetast. De wortels bleven blank tot de stengel geheel dood was. Een derde serie kolven werd in het voorjaar beplant met aardappelspruiten. In deze serie was een gedeelte der kolven voorzien van Knop-agar plus saccharose. Deze serie werd in een kas ondergebracht, waarbij een derde gedeelte werd geplaatst in een ruimte van 15° C, een derde gedeelte bij 18° C en een derde gedeelte bij 22° C. De aantasting verliep bij deze serie nog langzamer dan bij de tweede. Het duurde zes weken voordat de helft van de planten, die bij 22° stonden, was aangetast. Van de planten die bij 18° stonden, waren slechts enkele aangetast en de planten die bij 15° stonden, waren alle nog gezond.

In de kolven, waaraan saccharose was toegevoegd, was een sterke schimmelontwikkeling waar te nemen, terwijl ook grote sclerotiën werden gevormd. Het aantal aangetaste planten was echter niet groter dan in de kolven zonder saccharose; wel bleven de planten op Knop-agar plus saccharose veel kleiner. Dit zou een gevolg kunnen zijn van voedselconcurrentie, maar ook van vergiftiging door stofwisselingsprodukten van de schimmel. Hierbij moet nog worden vermeld, dat in deze laatste serie behalve met een isolatie van aardappel ook met een isolatie van sla werd gewerkt. De isolatie van sla had in zes weken twee maal zoveel planten aangetast als die van aardappel.

DISCUSSIE

Groei van de aardappelplant bij aanwezigheid van P. filamentosa *op de wortels*

Uit de potproeven is gebleken, dat de aardappelplanten waarvan de wortels zich in met *P. filamentosa* besmette grond bevonden, in ontwikkeling niet achter bleven bij planten, die onder vergelijkbare omstandigheden groeiden zonder de schimmel op de wortels. Bij de planten die met hun wortels in besmette aarde groeiden, werd de schimmel op de wortels aangetoond, aantasting trad niet op. Dit resultaat bevestigt het vermoeden, dat in onze aardappelcultuur

slechts schade aan de plant wordt toegebracht als op stengels of stolonen necrosen tot stand komen. Nader onderzoek zal moeten uitmaken of de schimmel stofwisselingsprodukten kan voortbrengen, die de groei van de aardappelplant beïnvloeden.

Verschil in vatbaarheid tussen wortel en stengel

Ook in vitro bleek de stengel van de aardappelplant veel vatbaarder te zijn voor aantasting door *P. filamentosa* dan de wortel. In sommige gevallen waren de bladeren nog weer vatbaarder dan de stengel. Licht en temperatuur bleken de vatbaarheid van de plant voor de schimmel te beïnvloeden. Dit is in overeenstemming met eerder door schrijver dezes aan zaaisels van andere gewassen gedane waarnemingen (niet gepubliceerd), waarbij bleek dat de in deze zaaisels optredende uitval tengevolge van *P. filamentosa* kon worden tegengegaan dan wel worden bevorderd door de zaaipannen respectievelijk in het licht of in het donker te plaatsen.

De vergelijking van de pathogeniteit van twee *P. filamentosa*-isolaties, een van aardappel en een van sla, gaf geen aanwijzing dat de isolatie van sla minder virulent zou zijn voor aardappel dan de van aardappel verkregen isolatie; eerstgenoemde tastte zelfs in de tijd, waarover de waarnemingen zich uitstrekten, meer planten aan.

Betekenis van deze waarnemingen voor de praktijk

De isolaties van *P. filamentosa*, waarmede in deze proeven gewerkt werd, gedroegen zich als zwakke parasieten; de aan de plant aangerichte schade wordt in hoge mate door de uitwendige omstandigheden beïnvloed. Doordat het wortelstelsel van de aardappelplant vrijwel resistent schijnt te zijn voor de in Nederland voorkomende stammen van *Pellicularia* en de aantasting der stengels, indien deze eenmaal boven de grond zijn, een sterk plaatselijk karakter draagt, is het te begrijpen dat de Rhizoctonia-ziekte in vele gevallen de opbrengst van het gewas nauwelijks beïnvloedt. De gevaarlijke periode voor het gewas is die tussen het poten en het opkomen. Door deze periode zo kort mogelijk te doen zijn, kan men het risico van aantasting beperken. Een dergelijke verkorting is te bereiken door bij het bepalen van het tijdstip van poten rekening te houden met de temperatuur van de grond en voorts door ondiep poten van voorgekiemd pootgoed. Het is te verwachten, dat men door deze factoren in acht te nemen de schade in het gewas zal kunnen beperken.

SAMENVATTING

Bij het onderzoek van aardappelplanten in met *Pellicularia filamentosa* besmette velden trokken twee verschijnselen de aandacht:

1. De schimmel werd veelvuldig gevonden op planten die geen ziekteverschijnselen vertoonden.
2. Aantasting door de schimmel bleef beperkt tot stengels en stolonen; de wortels waren steeds gezond.

Deze waarnemingen leidden tot enige proeven in potten en in vitro, waarbij het volgende werd gevonden:

1. Aardappelplanten in potten groeiden onbelemmerd ondanks de aanwezig-

heid van *P. filamentosa* op de wortels, als werd voorkomen dat de stengels werden aangetast.

2. Aardappelspruiten, die op Knop-agar tot beworteling werden gebracht en daarna werden geïnfecteerd met *P. filamentosa*, werden via stengel of blad aangetast. De wortels bleven steeds gezond zolang de stengel nog leefde.
3. De uitwendige omstandigheden hadden grote invloed op de resistentie van de plant. Bij veel licht en een temperatuur van ongeveer 15°C bleven de planten vele weken onaangetast. Bij weinig licht en een temperatuur van ongeveer 20°C waren de spruiten in 7 tot 10 dagen geïnfecteerd.
4. Als door toevoeging van saccharose aan de Knop-agar een zeer welige schimmelgroei mogelijk werd gemaakt, bleven de spruiten sterk achter in ontwikkeling. Dit kan een gevolg zijn van voedselconcurrentie, maar ook van vergiftiging door stofwisselingsprodukten van de schimmel.

SUMMARY

In the field it was noted that *Pellicularia filamentosa* often occurs on potato plants showing no symptoms of disease. If plants were found attacked, the lesions only appeared on stems and on stolons but not on roots. These observations led to experiments on potted plants and on sprouts growing on Knop-agar in the presence of *P. filamentosa*.

It was found that potato plants can develop normally in soil infested with *P. filamentosa* if attack of stems and stolons could be prevented. *In vitro* rooted sprouts were always attacked through the stems or through the leaves, the roots remaining healthy as long as the stems remained alive. Light and temperature were important factors with regard to the resistance of the potato sprouts. In autumn sprouts growing on agar and kept in a greenhouse at a temperature of about 20 C were infected within 7 to 10 days, but by artificial illumination this period could be extended to more than 4 weeks. In spring, with plenty of daylight, the plants were found to be highly resistant at a temperature of 15°C; infection was slight at 18°C and severe at 22°C.

If, by adding saccharose to the Knop-agar, abundant growth of the fungus was made possible, the sprouts made very little growth, but the number of infections was not increased. The retarded growth of such sprouts may be due to competition for food or may be caused by some substance produced by the fungus.

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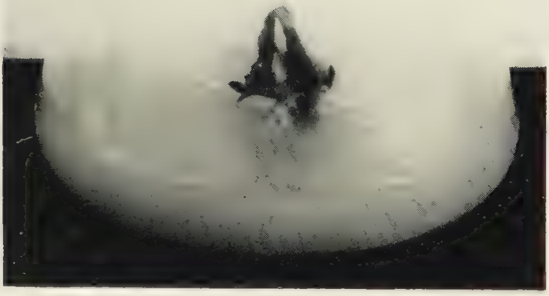

FIG. 2. Spruit van aardappel groeiend op Knop-agar en geïnfecteerd met *Pellicularia filamentosa* door een stukje van een cultuur op een der wortels te leggen. De stengel is geïnfecteerd, maar de wortels zijn gezond gebleven.

Sprout of potato growing on Knop-agar and inoculated with Pellicularia filamentosa *by placing a piece of the fungus culture on one of the roots. Infection has occurred on the stem, but the roots are still healthy.*

RESULTS OF SOME EXPERIMENTS ON THE CONTROL OF COMMON SCAB OF POTATOES BY CHEMICAL TREATMENT OF THE SOIL

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REPRINT FROM EUROPEAN POTATO JOURNAL, VOL. 1 (1958), No. 2 (JUNE)

RESULTS OF SOME EXPERIMENTS ON THE CONTROL OF COMMON SCAB OF POTATOES BY CHEMICAL TREATMENT OF THE SOIL[1]

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Summary in Eng., D. and Fr, See p. 23

1 INTRODUCTION

Since many of the most valuable varieties of potatoes are highly susceptible to common scab and as it is often inexpedient to control this disorder by maintaining a high soil acidity, growers in Holland are interested in other means of control. Accordingly in 1955 a series of experiments were started in order to investigate the value of various soil treatments which had been found promising by previous investigators. As such pentachloronitrobenzene (PCNB), mercuric chloride, borax, zineb and sulphur were tried.

Publications from GRAM (1944), HOOKER (1954), HOUGHLAND and CASH (1954), MEYER (1940), NUGENT (1956) and others give information on the use of PCNB. KENKNIGHT (1937), MEYER (1940), VAN DER SLIKKE (1935), and STÖRMER (1938) used mercuric chloride as an agent in potato scab control. Many writers mentioned the use of sulphur, amongst which are DUFF and WELCH (1927), LARSON *et al.* (1938), MACLEOD *et al.* (1939), MARTIN (1921), MUNCIE *et al.* (1944) and OTWALDS (1950). BAUSCH EN STRUYS (1954) suggested the probability of some influence of borium deficiency on the potato scab infection. No literature was present about the use of zineb in the control of potato scab; this fungicide was included to obtain information about the possibilities of the carbamates as soil disinfectants.

From the above mentioned materials only sulphur, PCNB and mercuric chloride were found effective.

2 METHODS

All experiments discussed below have been laid out in such a manner that statistical analysis of the results was made possible. Since the primary purpose of the experiments was to study the effect of the treatments on the incidence of scab rather than on yield, the size of the plots was kept down to 4 rows of 9 plants in the experiments where 6 replications were used and to 7 rows of 7 plants when the number of replications was only 4. By using the innermost 14 plants from the plots of 36 and the innermost 25 plants from the plots of 49 a sufficiently large number of tubers were obtained, to permit taking for assessment from each plot a sample of 5 kg from the size bracket 35–45 mm. Such a sample contained about 100 tubers.

[1] Received for publication Dec. 1957.

In 1957 the experiments were repeated with larger plots in order to be able to compare various methods of application with regard to scab control and influence on yield. Assessment of scab-incidence was done by grading each individual tuber according to its scabbiness into one of the following classes.

(1) free from scab
(2) 0–10 % of the surface area covered with scab
(3) 10–30 % of the surface area covered with scab
(4) 30–60 % of the surface area covered with scab
(5) more than 60 % of the surface area covered with scab.

From the weight of the tubers in each bracket an estimate for the scabbiness of the sample could be calculated. Although an estimate thus obtained permits comparison of samples and detection of statistically significant differences, the method is open to criticism, since the grading of the tubers depends on the ability of the individual. Therefore the weight of the scab free tubers in each sample was also determined and expressed as a percentage of the total sample weight. Thus an estimate of the scabbiness of the sample is obtained which is independent of the personal skill of the experimenter.
Although elimination of the personal element is an advantage, this method is only of limited use, since the number of completely clean tubers become zero as the samples get more severely scabbed.

3 STATISTICAL ANALYSIS

All experimental data were (after suitable transformation for equalizing variances) statistically analysed, according to the F-test.
Significance of differences between treatments was decided upon by the „range-test" (KEULS 1952, FEDERER 1955).

4 EXPERIMENTAL

In 1955 four experiments were carried out. Three had the same layout (randomised block) but were situated in different provinces. In these experiments the treatments were:

(1) PCNB 200 kg/ha
(2) PCNB 100 kg/ha
(3) mercuric chloride 16 kg/ha
(4) zineb 20 kg/ha
(5) borax 50 kg/ha
(6) control.

All chemicals were applied at the time of planting in such a manner that the greater part of the material fell in the row and came in direct contact with the tuber. PCNB and borax were applied as a dry powder. Mercuric chloride and zineb were mixed with water and applied at a rate of 250 cc per tuber.

The results of these three experiments are given in table 1.

TABLE 1. Influence of soil treatment with fungicides on the incidence of common scab on potato (Eigenheimer)

Treatment in kg/ha	Experiment 1955-I		Experiment 1955-II		Experiment 1955-III	
	surface area scabbed	% scab free tubers by weight	surface area scabbed	% scab free tubers by weight	surface area scabbed	% scab free tubers by weight
PCNB 200	6.8%	24%	9.2%	30%	4.4%	42%
PCNB 100	7.5%	22%	10.1%	28%	4.4%	42%
$HgCl_2$ 16	8.0%	31%	5.1%	40%	5.9%	39%
zineb 20	14.7%	2%	15.7%	3%	15.9%	9%
borax 50	26.5%	0%	18.0%	2%	23.0%	6%
control	13.2%	2%	20.0%	0%	17.9%	2%
Behandlung in kg/ha	*Fläche mit Schorfbefall*	*% schorffreie Knollen (gewogen)*	*Fläche mit Schorfbefall*	*% schorffreie Knollen (gewogen)*	*Fläche mit Schorfbefall*	*% schorffreie Knollen (gewogen)*
	Versuch 1955–I		*Versuch 1955–II*		*Versuch 1955–III*	

TABELLE 1. *Einfluss der Bodenbehandlung mit Fungiziden auf den Schorfbefall bei Kartoffeln (Sorte „Eigenheimer")*

From this table it is clear, that PCNB and $HgCl_2$ have in all three cases considerably reduced the incidence of scab. In all three experiments the difference between PCNB and mercuric chloride on one hand and control on the other was significant at the 1 % level. In experiment 1955-II, on a sandy loam, containing a clay fraction of about 20 %, the effect of mercuric chloride was significantly better than the effect of PCNB. In the other experiments PCNB and $HgCl_2$ appear to have been equally effective.
It is noteworthy that PCNB gave the same degree of control at both levels of application. In two out of three experiments borax had an adverse effect, which was, however, only significant in 1955-I.
In a fourth experiment carried out in 1955 PCNB, mercuric chloride and zineb were applied after the soil had either been treated with lime or with sulphur. The layout of this experiment was a 4 × 4 latin square in which the four treatments were:

(1) lime at 3000 kg/ha
(2) lime at 6000 kg/ha
(3) sulphur at 1000 kg/ha
(4) sulphur at 2000 kg/ha

Each plot was split into four sub-units, the sub-unit treatments being:

(1) PCNB at 200 kg/ha
(2) $HgCl_2$ 16 kg/ha
(3) zineb 20 kg/ha
(4) untreated.

CONTROL OF COMMON SCAB

The method of application of the fungicides was the same as described above. The results are given in table 2, which also shows the analysis of the crop obtained from this same field in 1956 and 1957.

Although the field was planted to potatoes in three consecutive years, the chemicals were applied only once i.e. in April 1955.

TABLE 2. Influence of application of Lime and Sulphur on the incidence of Common Scab and the results obtained with PCNB and $HgCl_2$ on the treated soil. All chemicals were applied once only, i.e. in April 1955.

Treatment	Harvest 1955		Harvest 1956		Harvest 1957	
Lime 3000 kg/ha	Soil pH (KCl) 5.1–6.0		Soil pH (KCl) 6.0		Soil pH (KCl) 6.0	
	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers
PCNB 200 kg/ha	4.3%	48%	9.1%	30%	39.1%	0%
$HgCl_2$ 16 kg/ha	6.0%	45%	19.3%	9%	34.4%	0%
Zineb 20 kg/ha	5.4%	44%	19.2%	6%	33.9%	0%
Control	12.3%	24%	28.7%	1%	40.8%	0%
Lime 6000 kg/ha	Soil pH (KCl) 5.1–6.2		Soil pH (KCl) 6.2		Soil pH (KCl) 6.2	
	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers
PCNB 200 kg/ha	3.4%	63%	9.1%	29%	29.1%	0%
$HgCl_2$ 16 kg/ha	3.3%	53%	19.7%	8%	37.8%	0%
Zineb 20 kg/ha	9.0%	28%	23.8%	4%	38.3%	0%
Control	11.5%	21%	34.2%	2%	43.9%	0%
Sulphur 1000 kg/ha	Soil pH (KCl) 5.1–5.1		Soil pH (KCl) 4.2		Soil pH (KCl) 4.2	
	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers
PCNB 200 kg/ha	2.8%	69%	7.1%	50%	13.2%	4%
$HgCl_2$ 16 kg/ha	5.1%	50%	8.3%	34%	14.9%	6%
Zineb 20 kg/ha	4.8%	58%	6.8%	46%	11.4%	7%
Control	4.0%	67%	6.6%	49%	16.1%	3%
Sulphur 2000 kg/ha	Soil pH (KCl) 5.1–4.9		Soil pH (KCl) 3.9		Soil pH (KCl) 3.8	
	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers	Surface area scabbed	Scab free tubers
PCNB 200 kg/ha	3.5%	63%	5.4%	56%	12.6%	15%
$HgCl_2$ 16 kg/ha	2.7%	73%	5.0%	48%	8.5%	17%
Zineb 20 kg/ha	3.1%	64%	3.9%	54%	7.7%	15%
Control	3.9%	50%	5.4%	52%	16.0%	11%
Behandlung	*Ernte 1955*		*Ernte 1956*		*Ernte 1957*	

TABELLE 2. *Einfluss der Anwendung von Kalk und Schwefel auf den Schorfbefall und die mit PCNB und $HgCl_2$ erzielten Ergebnisse auf den behandelten Boden. Alle Chemikalien wurden nur einmal angewandt, nämlich in April 1955.*

From table 2 it is to be seen, that sulphur did in general suppress scab to such an extent, that the influence of the fungicides is obscured. In the limed plots, however, PCNB and mercuric chloride both reduced the incidence of scab. For the first year the difference in incidence of scab for the treatments PCNB and mercuric chloride on one hand and control on the other was significant at the 1 % level.
The effect of PCNB remained significant at the 1 % level in the second year, while in the third year the fungicides were no longer effective. As to mercuric chloride, the effect of this chemical, although still present, was much less in the second year than in the first. It is interesting to note that the scab level becomes higher each year, even in the acidified plots. This is no doubt due to the continuous cultivation of potatoes.
In 1956 another series of experiments of similar layout was conducted from which borax and zineb were omitted. Since PCNB had not been more effective at 200 kg/ha than at 100 kg/ha, this chemical was only used at rates of 100 kg/ha and less. The treatment in the 1956 experiments were:

(1) PCNB 100 kg/ha
(2) PCNB 75 kg/ha
(3) PCNB 50 kg/ha
(4) PCNB 25 kg/ha
(5) $HgCl_2$ 16 kg/ha
(6) $HgCl_2$ 8 kg/ha
(7) untreated
(8) untreated.

The method of application was the same as in 1955, i.e. at the time of planting and in direct contact with the tuber. The results of the 1956 experiments are given in table 3. In experiment 1956-II mercuric chloride gave a better result than PCNB at 100 kg/ha. The same happened in 1955-II. These experiments were carried out in the same locality on a loamy soil with a clay fraction of about 20 %. In all other experiments, most of which were carried out on lighter soils, PCNB at 100 kg/ha gave at least as good a result or better than $HgCl_2$ at 16 kg/ha. At the level of 8 kg/ha control by $HgCl_2$ is less effective than at the 16 kg/ha level.
As to the level of PCNB, the figures of table 3, indicate, that although the highest rate of application is the most effective, even the lowest rate results in a considerable reduction of the surface area affected by scab. The difference in the percentage of scab free tubers for PCNB at 25 kg/ha and control is significant at the 1 % level.
In 1957 two more experiments were carried out for the purpose of investigating various methods of application. Up till then the only method used was application at the time of planting and in direct contact with the seed. The methods compared in 1957 were:

(1) Application 10 days before planting, on the ploughed land prior to preparation of the seedbed.

(2) Application 1 day before planting after preparation of the seedbed and followed by light harrowing.

TABLE 3. Influence of treatment of the soil with fungicides on the incidence of Common Scab (Eigenheimer)

Treatment	Experiment 1956 – I				Experiment 1956 – II			
	Crop lifted green		Crop lifted ripe		Crop lifted green		Crop lifted ripe	
Treatment in kg/ha	surface area scabbed	scab free tubers	surface area scabbed	scab free tubers	surface area scabbed	scab free tubers	surface area scabbed	scab free tubers
PCNB 100	2.0%	60%	2.7%	52%	1.5%	70%	1.6%	68%
PCNB 75	3.2%	51%	2.3%	60%	1.9%	63%	1.6%	67%
PCNB 50	3.3%	38%	2.8%	51%	2.3%	55%	1.8%	64%
PCNB 25	5.7%	34%	3.3%	39%	2.3%	53%	2.3%	59%
$HgCl_2$ 16	2.7%	58%	4.2%	40%	0.7%	86%	0.9%	82%
$HgCl_2$ 8	4.7%	27%	7.4%	21%	2.1%	58%	1.6%	69%
Control	20.4%	3%	19.6%	2%	3.9%	21%	4.9%	11%
Control	19.4%	3%	21.4%	3%	4.0%	20%	5.0%	20%
Behandlung in kg/ha	*Fläche mit Schorf*	*Knollen ohne Schorf*	*Fläche mit Schorf*	*Knollen ohne Schorf*	*Fläche mit Schorf*	*Knollen ohne Schorf*	*Fläche mit Schorf*	*Knollen ohne Schorf*
Behandlung	*grün geerntet*		*reif geerntet*		*grün geerntet*		*reif geerntet*	
	Versuch 1956–I				*Versuch 1956–II*			

TABELLE 3. *Einfluss der Bodenbehandlung mit Fungiziden auf Kartoffelschorf* (*Eigenheimer*)

(3) Application immediately after machine-planting and before earthing up.

In these experiments mercuric chloride, which had hitherto been used as a solution in water, was applied as a dry powder. This change was introduced because of the corrosive nature of this chemical which complicates application of the solution on a commercial scale.
Sulphur was used in these trials at the rate of 200 kg/ha. At this level it does not influence soil-acidity and if a scab controlling effect were to be found this would have to be attributed to fungicidal action.
The results of the 1957 experiments are represented in table 4.

Table 4 shows, that in both experiments only PCNB gave worthwhile control of scab. The difference between the percentage of scabfree tubers in PCNB at 60 kg/ha and control was significant at the 1 % level in both 1957 experiments.
Mercuric chloride was rather disappointing as compared to previous years. It is highly probable that this difference is to be attributed to its application as a solid. Sulphur at 200 kg/ha failed to give scab-control. With regard to PCNB it is to be noted, that the higher rate of application was the more effective, while the second method, i.e. broadcasting the day before planting after preparation of the seedbed gave a better result than either of the two other methods.

TABLE 4. Influence of soil treatment with PCNB, mercuric chloride and Sulphur on the incidence of Common Scab

	Experiment 1957-I (Eigenheimer)						Experiment 1957-II (Noordeling)		
	Crop lifted 29/7			Crop lifted 9/9			Crop lifted 7/8		
Treatment	Surface area scabbed	Scab free tubers	Yield gr/pl.	Surface area scabbed	Scab free tubers	Yield gr/pl.	Surface area scabbed	Scab free tubers	Yield gr/pl.
PCNB 60 kg/ha	1.*) 12	17	617	8	24	897	5	7	601
	2. 5	29	632	5	38	885	3	46	579
	3. 5	28	632	5	27	877	4	30	596
PCNB 90 kg/ha	1. 3	40	604	3	36	763	5	7	586
	2. 2	58	606	3	55	847	2	67	546
	3. 5	32	632	4	40	823	4	29	575
$HgCl_2$ 16 kg/ha	1. 11	1	639	11	3	873	6	4	590
	2. 9	9	688	8	6	882	5	20	553
	3. 9	7	692	7	10	856	6	4	605
Sulphur 200 kg/ha	1. 11	0	677	7	2	865	6	3	603
	2. 10	1	678	8	0	880	5	4	596
	3. 10	1	695	8	0	876	6	1	607
Control	12	0	657	11	0	831	7	1	573
Behandlung	*Fläche mit Schorf*	*Knollen ohne Schorf*	*Ertrag in Gramm je Pflanze*	*Fläche mit Schorf*	*Knollen ohne Schorf*	*Ertrag in Gramm je Pflanze*	*Fläche mit Schorf*	*Knollen ohne Schorf*	*Ertrag in Gramm je Pflanze*
	geerntet 29/7			*geerntet 9/9*			*geerntet 7/8*		
	Versuch 1957 I (Eigenheimer)						*Versuch 1957–II (Noorderling)*		

TABELLE 4. *Einfluss der Bodenbehandlung mit PCNB, Quecksilberchlorid und Schwefel auf den Kartoffelschorfbefall*

* Figs. 1, 2 and 3 refer to the moment of application of the chemical; see text p. 18.

* *Die Angaben 1, 2 und 3 beziehen sich auf den Augenblick der Anwendung der Chemikalien; siehe Text Seite p. 18*

EFFECT OF THE CHEMICALS ON GROWTH AND ON YIELD

In almost every experiment the plots treated with PCNB and with $HgCl_2$ showed delayed emergence. Because of the small size of the plots in 1955 and in 1956 the figures on yield did not permit detection of statistically significant differences, but in both years the impression was gained that a loss of crop amounting to about 10 % might be expected.

In the year 1957 when the plots were larger, the delayed emergence caused by PCNB and $HgCl_2$ was made up for by the control of *Rhizoctonia solani* which caused an uneven stand in the untreated controls. Hence no significant differences were found.

DISCUSSION

Pentachloronitrobenzene

Applied at the rate of about 100 kg of active substance per ha PCNB considerably reduced the incidence of common scab in highly susceptible varieties. In three experiments a higher rate of application was also used, but this did not result in better scab-control. If applied at lower rates, control is usually slightly less, but in one experiment even 25 kg ha gave a very much cleaner crop than the untreated control. Since the adverse effect of the chemical on early development also increases with the rate of application, the optimal dosage should be determined experimentally.

In case *Rhizoctonia solani* is prevalent in the area, PCNB will also control this disease to a large extent. As to the method of application, it was found, that broadcasting the chemical shortly before planting and earthing up, after preparation of the seedbed gave better control than either application 10 days before planting or application after planting and before earthing up.

In one experiment, where potatoes were planted for three years in succession PCNB was found to have a residual effect lasting into the second year, but not into the third year. Continuous cropping with potatoes was found to cause a marked increase in the incidence of scab.

Mercuric chloride

Used at the rate of 16 kg ha and applied as a solution in water at 250 cc per plant, $HgCl_2$ gave good control of scab. On a soil containing a clay fraction of about 20 % the result was better than on lighter soils. Apparently this chemical depends for its action on even distribution through the soil and on a certain degree of absorption in the top soil. When mercuric chloride was applied as a dry powder, it was found to give poor control of scab. Handling of a solution of mercuric chloride on a commercial scale is however not an attractive proposition for the farmer.

Sulphur

If sulphur is applied in quantities sufficient to lower the soil pH, good control of scab is to be expected. But even if a high soil acidity is maintained, the incidence of scab will increase if the land is cropped continuously with potatoes.

The fact that sulphur applied at the rate of 200 kg/ha failed to control scab, indicates that it has no fungicidal action against the scab organism in the soil.

Comparison of results obtained with those of previous investigations

PCNB

The results obtained with PNCB are in general in agreement with those obtained by the authors mentioned in the introduction. So GRAM (1944) reported reduction of incidence of potato scab and *Rhizoctonia* by gifts of 60 and 100 kg PCNB ha and he also found a residual effect in the next year.
HOOKER (1954) used 500 lbs and 1000 lbs/acre in broadcast applications; when incorporated in the furrow, however, 200 lbs/acre already appeared to be effective. In contradistinction to other investigations no phytotoxic effect was noted.
Phytotoxicity at a level of 150 lbs/acre is reported by HOUGHLAND and CASH (1954). They obtained very satisfactory results in scab control with applications of 100, 150 and 200 lbs/acre applied in the row, but at the dosage of 200 lbs acre a significant decrease in total yield and a depression in vine growth were evident. These results are in complete agreement with those described in the present paper.
MEYER (1940) noted a marked difference by broadcast applications and applications in the furrow. In the furrow good results were obtained with 48 kg ha, whilst broadcast applications became effective at a rate of 240 kg/ha (100 % PCNB).
NUGENT (1956) used 58, 116 and 174 lbs active material/acre. At 174 lbs acre the results were disappointing, indicating lack of thorough mixing of the materials in the soil.

Mercuric chloride

As to the use of mercuric chloride the opinions of the different investigations are not always in agreement with each other. So KENKNIGHT (1937) obtained negative results with mercuric chloride. The explanation given is the different sensitiveness of the various soil actinomycetes. If a great number of antagonistic *Actinomyces spec.* are eliminated by the mercuric chloride the possibility of increased incidence of scab is obvious.
On the other hand MEYER (1940) and VAN DER SLIKKE (1935) got favourable results with 0.4 g in 800 cc water and 0.25 g in 250 cc water/plant, respectively.
STÖRMER (1938) added 1 % $HgCl_2$ to the phosphate fertilizer and noted a beneficial effect on scab control, but also a retarding effect on growth of the potato plant, in accordance with the findings of VAN DER SLIKKE (1935) and the writers of this article.

Sulphur

With regard to sulphur the generally accepted opinion is that its activity is mainly due to its influence on soil acidity.
DUFF and WELCH (1927) however do not confirm the correlation between scab control by sulphur and influence on soil acidity. The results of the other writers mentioned

in the introduction are in agreement with the findings reported in this article, i.e. that a positive correlation between pH and scab incidence does exist.
MARTIN (1921) arrives at the conclusion that the effectiveness of S-gifts is increased by inoculation with sulphur oxidizing bacteria.
The authors of the present paper used uninoculated S with good results. In accordance with the work of OSWALD (1950) they found a distinct action in the second year.

SUMMARY

RESULTS OF SOME EXPERIMENTS ON THE CONTROL OF COMMON SCAB OF POTATOES BY CHEMICAL TREATMENT OF THE SOIL

(1). PCNB was found to lower the incidence of common scab if applied shortly before planting and earthing up, after préparing the seed-bed. Under conditions prevailing in the Netherlands and when using susceptible varieties the optimal rate of application may range between 60 and 100 kg of active substance per ha. A residual effect was found to last into the second year but not into the third. The chemical has a tendency to retard early development of the crop. This may, however, be made up for by its control of *Rhizoctonia solani*.
(2). Mercuric chloride applied at the rate of 16 kg/ha dissolved in water gave good control of common scab. If applied as a powder, the result is disappointing.
(3). Acidification of the soil by application of sulphur reduces scab incidence. Sulphur was not found to have a fungicidal action against the scab organism in the soil.
(4). Cultivation of potatoes for three consecutive years resulted in increased incidence of scab, even in soil acidified by the application of sulphur.

ZUSAMMENFASSUNG

ERGEBNISSE EINIGER VERSUCHE ZUR BEKÄMPFUNG VON KARTOFFELSCHORF DURCH CHEMISCHE BODENBEHANDLUNG

(1) PCNB verminderte das Auftreten von Schorf, wenn es kurz vor der Pflanzung und Ankäufelung verwendet wurde, nach Vorbereitung des Saatbettes. Unter holländischen Verhältnissen und bei Verwendung von anfälligen Sorten dürfte die optimale Menge des Bekämpfungsmittels schwanken zwischen 60 und 100 kg an aktiver Substanz je Hektar. Eine Nachwirkung wurde festgestellt im zweiten Jahre, aber nicht mehr im dritten. Der chemische Stoff hat eine Neigung, die frühzeitige Entwicklung der Kultur zu verzögern. Dies wurde jedoch bei der Bekämpfung von *Rhizoctonia solani* beobachtet.
(2) Quecksilberchlorid, im Verhältnis von 16 kg je Hektar verwendet, in Wasser gelöst, erwies sich als ein gutes Mittel zur Bekämpfung von Kartoffelschorf. In pulverisierter Form ist das Ergebnis dagegen enttäuschend.
(3) Säuerung des Bodens durch Anwendung von Schwefel reduziert den Schorfbefall. Von Schwefel ist keine fungizide Einwirkung auf die Schorforganismen im Boden festgestellt worden.
(4) Anbau von Kartoffeln in drei aufeinanderfolgenden Jahren hatte einen zunehmenden Schorfbefall zur Folge, auch in Boden, der durch Anwendung von Schwefel gesäuert war.

RÉSUMÉ

RÉSULTATS OBTENUS DANS DES ESSAIS ENTREPRIS POUR COMBATTRE LA GALE COMMUNE DE LA POMME DE TERRE PAR TRAITEMENT CHIMIQUE DU SOL

1°. P.C.N.P. a réduit les attaques de la gale commune, lorsque appliqué peu avant la plantation et le buttage dans une couche de semis préparée auparavant. Dans les conditions régnant en Hollande et à l'utilisation de variétés sensibles à la gale commune la quantité optimum du moyen

de lutte pourrait osciller entre les 60 et 100 kilogrammes en substance active à l'hectare. L'effet de ce traitement fut encore perceptible dans la deuxième année, il fut cependant nul dans la troisième année. La substance chimique a tendance à retarder le développement précoce de la végétation. C'est que cela fut constaté au moins à la lutte contre la gale rhizoctonienne (*Rhizoctonia solani*).

2°. Chlorure mercurique appliqué dans un dosage de 16 kilogrammes à l'hectare, dissous dans de l'eau, s'est avéré un moyen efficace dans la lutte contre la gale commune de la pomme de terre. Sous forme pulvérisée par contre, le résultat est décevant.

3°. L'acidification du sol par l'application de soufre réduit les attaques de la gale commune. On n'a pas pu constater que le soufre a eu des effets fongicides sur les agents vecteurs de la gale commune dans le sol.

4°. La culture de la pomme de terre dans trois années successives a eu des attaques accrues de la gale commune pour conséquence, aussi dans les sols qui ont été acidifiés par l'application de soufre.

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